Almost all astronomical information is obtained through the light we receive from cosmic objects
1) To investigate the nature of light

2) To become familiar with the electromagnetic spectrum

3) To understand how light interacts with matter (information contained in light)
What is light?

- **Energy**
  - Sometimes called “radiant energy”
  - Think – solar power, photosynthesis, the fireplace ...

- **Information**
  - the signal received by your car radio
  - the signals received by telescopes staring at stars
  - the signals received by your eyes right now!
Light as a wave

- Waves you can see:
  e.g., ocean waves

- Waves you cannot see:
  - sound wave
  - electromagnetic waves

Light is an electromagnetic wave
What is the electromagnetic wave?

It is electricity and magnetism moving through the space.
Properties of Waves

- **Wavelength** – the distance between crests (or troughs) of a wave.
- **Frequency** – the number of crests (or troughs) that pass by each second.
- **Speed** – the rate at which a crest (or trough) moves.

For light in general:

\[ \lambda \nu = c \]

- Speed of light = \(3 \times 10^5\) km/s
A wave traveling at a speed of 90 meters per second with a frequency of 60 Hz would have a wavelength of

- 5400 meters
- 540 nm
- 1.5 meters
- 60 meters
Light as particles

- Light comes in quanta of energy called *photons* – little bullets of energy.
- Photons are massless, but they have momentum and they react to a gravitational field.
All types of electromagnetic radiation act as both waves and particles.

The two views are connected by the relation

\[ E = h \nu \]

\( h \) is the Planck's constant
A photon's energy depends on the wavelength (or frequency) only, not the intensity.
It turns out that particles of matter, such as electrons, also behave as both wave and particle.

The theory that describes these puzzles and their solution, and how light and atoms interact is quantum mechanics.
Properties of Light

- All light travels with a velocity $= 3 \times 10^5$ km/s
- The frequency (or wavelength) of photon determines how much energy the photon has.
- Light can be described in terms of either energy, frequency, or wavelength.
Visible Light

Shorter Wavelength

Longer Wavelength
But visible light isn’t the whole story. It’s just a small part of the entire electromagnetic spectrum.

Short Wavelength
(high frequency)
(high energy)

Long Wavelength
(low frequency)
(low energy)
Electromagnetic Radiation

- Short wavelength
- Long wavelength
Compared to visible light, radio waves have:

- higher energy and longer wavelength
- higher energy and shorter wavelength
- lower energy and longer wavelength
- lower energy and shorter wavelength
- all light has the same energy
Matter interacts with light in four different ways:

- **Absorption** – the energy in the photon is absorbed by the matter and turned into thermal energy
  - E.g., Your hand feels warm in front of a fire.

- **Reflection** – no energy is transferred and the photon "bounces" off in a new (and predictable) direction
  - E.g., Your bathroom mirror

- **Transmission** – no energy is transferred and the photon passes through the matter unchanged.

- **Emission** – matter gives off light in two different ways. We’ll come back to this next lecture.
Absorption

Photon deposits energy into material. Thermal energy is increased and the material gets warmer.
Transmission

Photon passes through material without depositing energy. Everything remains unchanged.
Photon reflects off of material. No energy is lost but outgoing photon has a new direction.
These processes depend on both the material and the wavelength of the photon.
Sun seen in optical and Ultraviolet
Sun seen in X-ray

X-ray
Our eyes work via the process of:

- transmission
- reflection
- absorption
- emission
- none of the above
A red ball is red because:

- it only emits frequencies corresponding to red
- it only reflects frequencies corresponding to red
- it only transmits frequencies corresponding to red
- it only absorbs frequencies corresponding to red
This shape is red because:

- the projector is only emitting frequencies corresponding to red
- that spot on the screen is only reflecting frequencies corresponding to red
- that spot on the screen only transmits frequencies corresponding to red
- that spot on the screen only absorbs frequencies corresponding to red